State of the Art (SOTA)
Manual for the Glass Industry

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Air Quality Permitting Program

State of the Art (SOTA)
Manual for the Glass Industry
Section 3.15

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3.15.ii ABBREVIATIONS

ACT	Alternative Control Techniques
BACT	Best Available Control Technology
CE	Cost Effectiveness
CFR	Code of Federal Regulations
CO	Carbon Monoxide
DOE	Department of Energy
EPA	Environmental Protection Agency
ESP	Electrostatic Precipitator
LAER	Lowest Achievable Emission Rate
LEA	Low Excess Air
LNB	Low NO_X Burners
LOF	Libbey-Owens-Ford
NJAC	New Jersey Administrative Code
NJDEP	New Jersey Department of Environmental Protection
NO_X	Oxides of Nitrogen
NSPS	New Source Performance Standard
OEAS	Oxygen Enriched Air Staging Technology
PSD	Prevention of Significant Deterioration
PM	Particulate Matter
RACT	Reasonably Achievable Control Technology
SCAQMD	South Coast Air Quality Management District
SCR	Selective Catalytic Reduction
SD	Spray Dryer
SNCR	Selective Non-Catalytic Reduction
SJUAPCD	San Joaquin Valley Unified Air Pollution Control District

3.15.ii ABBREVIATIONS (cont.)

SOTA	State of the Art
SOX	Oxides of Sulfur
US EPA	United States Environmental Protection Authority
VOC	Volatile Organic Compound
VPSA	Vacuum Pressure Swing Adsorption

3.15 STATE OF THE ART MANUAL FOR THE GLASS INDUSTRY

3.15.1 SCOPE

This manual identifies State of the Art (SOTA) performance levels for new glass manufacturing furnaces. SOTA for modified or reconstructed furnaces as defined by N.J.A.C. 7:27-8 or N.J.A.C. 7:27-22 must be demonstrated by a case-by-case determination. These SOTA levels apply to the following segments of the Glass Industry:

Soda Lime Recipe Glass

- Commercial Container Glass - Clear and colored glass formed into bottles, jars, ampules, or other containers.
- Specialty Container Glass - Glass produced to meet the specifications of cosmetic, pharmaceutical, or scientific industries.
- Flat Glass - Window glass, plate, rolled, wire, tempered, or laminated glass, produced for the construction and automotive industries.
- Pressed and Blown Glass - Textile glass fibers, lighting, electronic, optical and technical glass including kitchen and art-ware glass for industrial and commercial use.

Borosilicate Recipe Glass

- Pressed and Blown Glass - Textile glass fibers, lighting, electronic, optical and technical glass including kitchen and art-ware glass for industrial and commercial use.

Wool Fiberglass

- Insulation materials used in the construction industry.

3.15.2 SOTA PERFORMANCE LEVELS

Table 1 summarizes the SOTA performance levels. The levels are based on an examination of permits issued by the New Jersey Department of Environmental Protection, state regulations and permits issued from state and local agencies in California, Georgia, Illinois, Indiana, Massachusetts, Pennsylvania, Texas, and Wisconsin, federal regulations and data from the US EPA’s RACT/BACT/LAER Clearinghouse Information System.

These levels apply to furnaces. However, SOTA applies to other glass processes such as batching and forming. PM is controlled in the batching operation with baghouse (fabric filter) technology for the elevators, conveyors and silos. The PM requirements for glass furnaces in 40 CFR 60, Subpart CC - Standards of Performance for Glass Manufacturing Plants is considered SOTA. VOC is sometimes controlled by incorporating a silicone-water emulsion in the process replacing the hydrocarbons previously used with the molds. CO is controlled using good combustion technology. SO_2 controls are not recommended at this time. However, SO_2 controls will be considered for recommendation in future revisions of this manual.

Table 1
New Jersey Glass Manufacturing SOTA Performance Levels

Glass Industry Segment	Recipe	Performance Level lb/ton of Glass Produced
Commercial Container Glass	Soda lime	NO_X: 4.0 lb/ton PM: 0.2 lb/ton (Nat. Gas Fuel) PM: 0.26 lb/ton (Oil Fired)
Specialty Container Glass	Soda Lime	NO_X: Case-by-case PM: 0.2 lb/ton (Nat. Gas Fuel) PM: 0.26 lb/ton (Oil Fired)
Specialty Container Glass	Borosilicate	NO_X - Case-by-case PM at 1.0 lb/ton (Nat. Gas) PM at 1.3 lb/ton (Oil)
Flat Glass	Soda Lime	NO_X: 7.0 lb/ton PM: 0.45 lb/ton (Nat. Gas Fuel) PM: 0.45 lb/ton (Oil Fired)
Tableware	Soda Lime	NO_X: 5.5 lb/ton PM: 0.2 lb/ton (Nat. Gas Fuel) PM: 0.26 lb/ton (Oil Fired)
Pressed and Blown Glass	Soda Lime	NO_X: 4.0 lb/ton PM: 0.2 lb/ton (Nat. Gas Fuel) PM: 0.26 lb/ton (Oil Fired)
Pressed and Blown Glass	Borosilicate	NO_X - Case-by-case PM at 1.0 lb/ton (Nat. Gas) PM at 1.3 lb/ton (Oil)
Wool Fiberglass		NO_X: 4.0 lb/ton PM: 0.5 lb/ton (Nat. Gas Fuel) PM: 0.55 lb/ton (Oil Fired)

Note: Emission levels are one hour averages

There are several important considerations regarding the SOTA performance levels identified below. First, tableware has been identified separately in the table below because there is evidence that the primary SOTA technology (i.e., oxy-fuel) may not be appropriate for this specialized industry segment. Second, SOTA documentation for NO_X for specialty glass furnaces (soda lime and borosilicate recipes) and borosilicate recipe pressed and blown glass will be by a case-by-case determination. SOTA performance levels cannot be specified for these categories of furnace because of the variations in the nitrate content of the formulae. However, SOTA technology for these furnace types is oxy-fuel or an equivalent technology. Third, the SOTA performance levels for NO_X include a factor to account for deterioration of the furnace that could allow air infiltration and reduce the effectiveness of oxy-fuel. However, no furnace using oxy-fuel has yet completed a full campaign. Therefore, it is appropriate that a furnace equipped with oxy-fuel or another technology that has not been tested through a complete campaign to have permit conditions that accommodate the possibility that more severe deterioration will occur.

3.15.3 Technical Basis and References

To define SOTA performance standards for the glass manufacturing industry, the following sources of information were used: 1) Recent New Jersey permits; 2) EPA's RACT/BACT/LAER Clearinghouse; 3) EPA's Control Technology Center; and 4) Information from other State and local air pollution control agencies.

Table 2
Basis for New Jersey Glass Manufacturing SOTA

Glass Industry Segment	Recipe	Pollutant	Basis
Commercial Container Glass	Soda lime	NO_X PM	Permits for sources in California and other States NSPS Subpart CC
Specialty Container Glass	Soda Lime	NO_X PM	Industry Presentation NSPS Subpart CC
Specialty Container Glass	Borosilicate	NO_X PM	Industry Presentation NSPS Subpart CC
Flat Glass	Soda Lime	NO_X PM	Permits for sources in California and other States NSPS Subpart CC
Tableware	Soda Lime	NO_X PM	Industry Presentation NSPS Subpart CC
Pressed and Blown Glass	Soda Lime	NO_X PM	Permits for sources in California and other States NSPS Subpart CC
Pressed and Blown Glass	Borosilicate	NO_X PM	Industry Presentation NSPS Subpart CC
Wool Fiberglass		NO_X	Permits for sources in

Glass Industry Segment	Recipe	Pollutant	Basis
		PM	California and other States NSPS Subpart CC

Appendices B and C provide more detailed discussions on the data and analyses used to determine the SOTA performance levels for oxides of nitrogen and particulate matter. The data in Appendix B shows that there are a significant number of furnaces in California and other States that have been permitted and/or are achieving NO_X emission levels below the recommended SOTA performance levels. However, there is insufficient evidence now as to the ability of these furnaces to achieve the same levels as they age. Therefore, it was decided to use higher levels to allow for the possibility that emission rates may increase as furnaces age. The performance levels recommended are the same as those included in the RACT regulations in the San Joaquin Valley of California. Similarly, the information available for recently permitted furnaces indicate a variety of emission levels for PM. Most of these are expressed in terms of gr/dscf. These levels are not directly comparable to the levels in the NSPS because data on the exhaust gas flow rate and pull rate of these furnaces were not available. However, some of the recently permitted furnaces have levels that are the same as the NSPS. Therefore, using the NSPS as SOTA will be consistent with recent permitting experience in a number of States.

Technologies listed in Table 3 are currently demonstrated in the glass manufacturing industry. Refer to Appendix D for additional information on the NO_X Control Technologies and Appendix E for additional information on the PM Control Technologies.

Table 3. Control Technologies for Achieving Compliance[1].

		Control Technologies	
Glass Industry Segment	**Recipe**	**NO_X**	**PM**
Commercial Container Glass	Soda Lime	Oxy-fuel	ESP
		Control Technologies	
Glass Industry Segment	**Recipe**	**NO_X**	**PM**
Specialty Container Glass	Soda Lime	Oxy-fuel	ESP
Flat Glass	Soda Lime	3R	ESP/FF

[1]Any reference to trade names, specific commercial products, commodities, or services in this State of the Art (SOTA) Reference Manual is for the purpose of citing an example or illustration, and does not in any manner constitute an endorsement, recommendation, or opinion of suitability by the New Jersey Department of Environmental Protection (NJDEP) of the specific commercial products or services.

Pressed and Blown Glass	Soda Lime	Oxy-fuel	ESP
Pressed and Blown Glass	Borosilicate	Oxy-fuel	ESP
Wool Fiberglass		Oxy-fuel	

Note: The technologies listed above are those that have been demonstrated on the particular processes. However, there is a possibility of technology transfer. Although it is unproven and has only been demonstrated on flat glass furnaces, there is no known reason, for example, why the 3R process cannot be used on container glass furnaces. However, oxy-fuel has not been suggested as a technology for flat glass furnaces because of potential alkaline corrosion problems. Electric boost has been able to reduce oxides of nitrogen emissions to these recommended SOTA levels. However, to attain these levels with electric boost may not be cost effective. Although electrostatic precipitators are commonly used to control particulate matter emissions from all types of furnaces, fabric filtration and high-pressure venturi scrubbers are other technologies which might be used to meet the recommended SOTA performance levels. Fabric filtration has been used when sulfur dioxide emissions are also controlled by injecting pulverized limestone into the gas stream, reacting it with the sulfur dioxide, and collecting it in a baghouse.

3.15.4 Recommended Review Schedule

The recommended review schedule is every three years. A review schedule of three years was selected for the following reasons:

- The glass industry in New Jersey is a mature industry that has not experienced much growth during the past few years. Therefore, a longer review cycle is warranted.

- Although new technologies are being developed and demonstrated, it is anticipated that this process will be longer for the glass industry than some others because of the industry's low growth rates and relatively long furnace replacement cycles.

- The pollutants of primary concern for the glass industry are oxides of nitrogen, particulate matter, and sulfur dioxide. Control technologies for these pollutants are relatively well defined. During the next review cycle, it is anticipated that existing control technologies will be applied more widely rather than that many more new technologies will be developed.

3.15.5 References

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3.15.6 SOTA MANUAL FOR THE GLASS INDUSTRY - APPENDICES

Appendix A

Industry Description

In this appendix, the glass industry is described. First, the various segments are discussed to establish the distinctions that are generally used to differentiate potentials to emit criteria pollutants. Second, a general discussion of the glass manufacturing process is provided to identify the portions of the process which have a potential to emit air pollutants.

Industry Segments

The glass industry consists of five segments: flat glass, glass containers, pressed and blown glass, wool fiberglass, and products of purchased glass. Approximately, 57 percent of all glass melted is produced by the glass container segment. The remaining glass melting is roughly divided between the flat glass (24 percent) and pressed and blown glass (19 percent) segments.

The glass industry categories include compositions of Soda Lime, Borosilicate, Aluminosilicate, or Lead Silicate, frit (powdered glass used for ceramic coatings), and some Phosphate glasses. Soda Lime glass accounts for nearly 90 percent of all the glass produced. It is used for containers, flat glass, pressed and blown ware, and lighting products where exceptional chemical durability or heat resistance is not required. Replacement of alkali by boric oxide in a glass network gives a lower expansion glass. Borosilicate glass is applied as ovenware, laboratory equipment, piping, and some automotive products.

- **Glass containers**

The glass containers segment is the largest of the three major segments of the glass industry. It includes the manufacture of narrow-neck and wide-mouth glass containers for foods, beverages, medicines, toiletries, and cosmetics. Three general types of container glass are produced: amber, green, and clear. Clear glass is designated “flint”. The major difference between amber and flint is the addition of iron oxides. Department of Commerce data indicated amber accounted for approximately 15 percent of glass production and flint represented about 85 percent.

There are approximately 10 manufacturers of glass containers in the United States. The five largest companies operate approximately half of the 61 plants. Geographically, glass container plants are located near the local markets they serve. Plants are found throughout the United States, but a large number are concentrated in the East, North-Central, and Middle Atlantic regions.

The basic raw materials for soda lime container glass are silica sand, soda ash ($NaCO_3$), and limestone (primarily $CaCO_3$, plus some $MgCO_3$ in dolomitic limestones). Feldspathic minerals (anhydrous aluminosilicates containing potassium, sodium, and calcium in varying ratios) are also utilized as sources of alumina and alkali. Minor amounts of other oxides are introduced as impurities, and additional minor ingredients are added for specific purposes. A typical soda lime glass-batch composition includes silica sand, soda ash, feldspar, limestone, and sodium sulfate. The minor ingredients such as salt cake and various fining, coloring, or decoloring agents, rarely exceed 5 percent and are often less than 0.1 percent of the total glass composition.

- **Pressed and Blown Glass**

The pressed and blown glassware industry essentially includes all industrial establishments in manufacturing specialty glass and glassware that is pressed, blown, or shaped from glass produced in the same establishment. Establishments include those manufacturing textile glass fibers; lighting, electronic, optical and technical ware; and machine-made and handmade table, kitchen, and art-ware glass products.

The pressed and blown glass consists of approximately 285 manufacturing establishments. Approximately 40 plants produce hand pressed and blown glassware almost exclusively. The industry is concentrated in or about the North Central region of the United States, primarily New York, New Jersey, Pennsylvania, West Virginia, Ohio, Indiana, and Illinois.

The four important categories of glass manufactured by the pressed and blown glass industry and respective percent of total volume are as follows: Soda Lime (77%), Borosilicate (11%), Lead Silicate (5%), and Opal (7%). Soda Lime glasses consist of a combination of silica sand (SiO_2), soda ash ($NaSO_3$), and limestone ($CaCO_3$ and $MgCO_3$). Borosilicate glasses are basically a combination of silica sand, boric oxide (B_2O_3), soda ash, and alumina (Al_2O_3). Lead silicate glasses are composed of silica, lead oxide, and significant amounts of alkali oxide. Opal glasses consist of silica, alumina, zinc oxide, and limestone and dolomitic limestone.

- **Flat Glass**

The flat glass industry contains establishments primarily engaged in manufacturing flat glass as well as some laminated and tempered glass. The major products shipped by the flat glass industry are: window glass, plate and flat glass, rolled and wire glass, tempered glass, and laminated glass. The construction and automotive industries drive the flat glass industry. Most of the 6 flat glass manufacturers are located in the North Central (Pennsylvania, Ohio, Michigan, Illinois) and South Central (Tennessee and Texas) regions of the United States, although California also has manufacturing plants. New Jersey has one operating flat glass plant.

Four flat glass products are manufactured in the United States: float, sheet, rolled, and plate. Of these float glass accounts for more than 90 percent of the total flat glass production. Float glass floats on a liquid alloy, usually tin, surface with simultaneous cooling to sheet glass. The composition of flat glass is exclusively soda, lime and silica.

- **Mineral Wool**

The mineral wool industry includes primarily those establishments involved in the production of fiberglass insulation products. Many of these facilities have fiberglass manufacturing lines with blowing wool areas. The fiberglass manufacturing line produces blankets of fiberglass insulation in nine steps. These process steps include raw material unloading and storage, batch weighing, raw material blending, glass melting, fiberizing and collecting (forming), curing, cooling, trimming and cutting, and packaging.

Manufacturing Processes

Most glass articles are manufactured by a process in which raw materials are converted at high temperatures to a homogeneous melt that is then formed into the articles. The configuration of the melting furnace is generally referred to as a regenerative end-port or side-port. In both configurations, the refractory-lined flues are used to recover the energy of the hot flue gas. The high temperature of the flue gas exiting the furnace heats the refractory material called a "checker". After the checker has reached a certain temperature, gas flow is reversed and the firing begins on the other side (or end) of the furnace. The checker that was at one time the exhaust checker now becomes the combustion air preheater. Typically the end-port furnaces are smaller, limited to less than 175 tpd, whereas the side-port furnaces are larger with some tanks rated at over 800 tpd. Conversion to oxy-fuel eliminates the need for port-end regenerators. Thus, there is no gas reversal process.

In container glass production, a typical system downstream of the melting tank consists of so called individual section machines in which molten glass "gobs" are fed into molds. The containers are then carefully cooled in the annealing section to relieve stresses introduced in the molding process.

In flat glass production, the molten glass coming from the firing section is pulled onto a batch of molten tin. As it flows over this batch, it is generally cooled from around 1950 to 1130 °F. It then enters an annealing section where it is further cooled.

In the pressed and blown production, products are formed by blow molding. An extremely wide range of operations can be used downstream. Though each operation shares the need for common heating/forming/cooling step, each of these operations uses vastly different machinery and processes.

Lead and borosilicate glasses may be produced in continuous reverbertory furnaces, but because of small size production, are often conducted in batch, rotary (including tilting), crucible, and hearth furnaces.

The glass manufacturing operation has been divided into the following processes: batching and mixing, melting, forming, postforming, and product packaging. Each of these is discussed below.

- **Batching and Mixing**

The first process in the manufacture of glass articles is the weighing and mixing/blending of the raw materials: sand, alkali, alkaline-earth carbonates, various mineral products, and cullet (scrap glass). The major materials used in production are cullet (broken, waste, or recycled glass), silica sand, and soda ash. The raw materials and cullet are accurately weighed, as specified by the particular glass recipe, and intimately mixed before delivery to the melting unit.

Cullet is used in both the container and flat glass industries. Cullet may consist of internally recycled glass from waste operations such as cutting and forming, or it may be externally recycled from glass returned from recycling operations. Because the chemical reactions necessary to form glass have already taken place in the cullet, less energy is needed to melt the cullet compared to virgin batch ingredients.

Bin vent filters on the storage silos are standard units supplied by the silo vendors for batch house operation. Fabric filters are used for collection of particulates emitted at the weigh-blending station. These are primarily pulse jet baghouses operating at an air-to-cloth ratio of 4-7 fpm.

- **Melting**

The glass melting operation is a high temperature combustion process and is the major source of emissions in the glass manufacturing operation. Natural gas and fuel oil are used as primary fuels in this step. Electric Boost is used extensively in combination with the fuels.

- **Forming**

Both pressed and blown glass containers are formed in automated machines. Various sprays and swabbing compounds are used in this process to facilitate the release of the formed product from the hot metal mold.

The forming process that is used in the manufacture of flat glass is considerably different from that used in pressed and blown glass and glass containers. In flat glass manufacturing, the molten glass floats onto a bath of molten tin and is drawn into a very large flat sheet.

- **Postforming**

In the flat glass industry, the forming and postforming are usually integrated into one continuous process. The primary function of the postforming operation is to remove detrimental, residual stresses in the glass product, and in that sense, forming and postforming operations in the flat glass manufacturing industry can be considered as being equivalent to similar operations in the other two glass manufacturing segments.

The postforming process includes annealing to remove detrimental, residual stresses in the glass products, lubricity coatings, and decorating. These operations generally use natural gas, as precise temperature control is required. Additionally, acid fumes may be present from etching and frosting operations.

- **Product Packaging**

Emissions from the product packaging step are non-existent or negligible. If emissions are present, they are in the form of paper dust from the packaging materials, which is a fugitive emission.

Appendix B

Analysis of SOTA Performance Levels for Oxides of Nitrogen

To determine the technical feasibility of a particular SOTA performance level, the task group compiled information from a variety of sources to identify the emission levels that have been achieved by the industry in New Jersey and elsewhere. In addition to recent New Jersey permits, the EPA's RACT/BACT/LAER Clearinghouse, the EPA's Control Technology Center, and State and local air pollution control agencies in California, Massachusetts, Pennsylvania, Illinois, and Texas were sources of information on recent advances in the control of oxides of nitrogen from glass furnaces. Recent permitting experience in the San Joaquin Valley in California was particularly important because a significant number of furnaces in that area have been controlled to a level that is more stringent than the RACT levels in New Jersey. The permitted levels achieved in the San Joaquin Valley are consistent with recently adopted RACT rules in that area. However, emission limits in the San Joaquin Valley's RACT rules are higher than the levels achieved to allow for possible deterioration with the aging of the furnaces. The San Joaquin Valley is a severe ozone nonattainment as is much of New Jersey. In the discussion below, specific instances of controls being used to achieve a more stringent level are described.

According to SCAQMD staff, Ball-Foster and Owens-Brockway have two container furnaces in Southern California that were converted to an oxy-fuel system, and are currently achieving less than 4.0 lb NO_X/ton of glass emissions level.

In 1988, the Department of Energy (DOE) funded a program to demonstrate the use of oxy-fuel in a large commercial glass furnace using oxygen produced at the furnace site from a plant using vacuum pressure swing adsorption (VPSA) technology. Praxair provided the oxygen, Corning supplied the oxy-fuel technology, and Gallo Glass Company of Modesto, CA agreed to be the host plant. Gallo had a 325 ton per day regenerative cross-fired container glass furnace. Gallo has been using the oxy-fuel system in their furnaces since 1991. Four Gallo furnaces that were converted to the oxy-fuel system have NO_X emission levels ranging from 1.5 to 2.9 lb NO_X per ton of glass based on furnace source test results. The results of the project were reported at the 1991 Glass Problems Conference and further documented in DOE publications (14, 15, 16).

The 3R process has been tested and is operational at Libbey-Owens Ford (LOF) flat glass furnace in Lathrop, California. The 3R source tests demonstrated that approximately 80% reduction from uncontrolled NO_X emission (11 lbs of NO_X/ton of glass pulled reduced to an average of 2.2 lb NO_X/ton of glass based on 3 source test runs).

These and other facilities that have been able to achieve an emission rate at or below the recommended SOTA performance level are listed in Table B-1.

Table B-1

Glass Furnaces that have achieved the SOTA Performance Limit for Oxides of Nitrogen

Company	Location	NO_X Level* (lbs/ton glass)	Basis for Determination	Control Technology
Owens - Brockway	Tracy, CA	2.4	RACT	Electric Boost
Owens - Brockway	Tracy, CA	3.7	RACT	Electric Boost
Gallo Glass	Modesto, CA	1.5	RACT	Oxy-fuel Burners
Gallo Glass	Modesto, CA	2.6	RACT	Oxy-fuel Burners
Gallo Glass	Modesto, CA	2.5	RACT	Oxy-fuel Burners
Gallo Glass	Modesto, CA	2.9	RACT	Oxy-fuel Burners
LOF	Lathrop, CA	2.2	Not Available	Gas Reburn
Owens Brockway	Los Angeles, CA B Furnace	<3.0**	Full-scale Field Test	Oxy-fuel Burners
Owens Brockway "B"	Chicago Heights, IL	4.1***	Not Available	Oxy-fuel Burners
Owens Brockway "A"	Atlanta, GA	3.6****	RACT	Electric Boost
Owens Brockway "B"	Atlanta, GA	3.6****	RACT	Electric Boost
Kimble Furnace S	Vineland, NJ	1.25*****		Oxy-fuel Burners

* Source test data
** Full-scale Field Test
*** Permitted Level (Calculated)
**** Based on source tests to prove compliance with RACT limit of 5.5 lb/ton. Electric boost is 8 and 9 percent respectively.
*****Based on the average of three test runs.

Appendix C

Analysis of SOTA Performance Levels for Particulate Matter

To determine the technical feasibility of a particular SOTA performance level, the task group compiled information from a variety of sources to identify the emission levels that have been achieved by the industry in New Jersey and elsewhere. In addition to recent New Jersey permits, the EPA's RACT/BACT/LAER Clearinghouse, the EPA's Control Technology Center, and State and local air pollution control agencies in California, Massachusetts, Pennsylvania, Illinois, and Texas were sources of information on recent advances in the control of particulates from glass furnaces.

These and other facilities that have been able to achieve an emission rate at or below the recommended SOTA performance standard are listed in Table C-1.

Table C-1
Glass Furnaces that have achieved the SOTA Performance Limit for Particulate Matter

Company	Location	PM Level*	Basis for Determination	Control Technology	Type of Furnace
Corning-Asahi Furnace #223	State College, PA	0.005 gr/dscf	NSR	ESP	Soda Lime
Corning-Asahi Furnace #222	State College, PA	0.1 g/kg	NSPS	ESP	Soda Lime
Corning-Asahi Furnace #221	State College, PA	0.04 gr/dscf	NSPS	ESP	Soda Lime
Ball-Foster	McKean Co., PA	0.04 gr/dscf	NSR	None	Soda Lime
St. George Crystal	Westmoreland Co., PA	0.005 gr/dscf	NSR	Baghouse	Electric
Owens - Brockway	Tracy, CA	0.1 gr/dscf	NSR		Soda Lime
Owens Brockway "J"	Streater, IL	1 lb/ton	NSR	None	Soda Lime
Owens Brockway "B"	Chicago Heights, IL	0.33 lb/ton**	NSR	ESP	Boro-silicate
PPG	Mt. Zion, IL	0.45 lb/ton	NSPS		Flat Glass
Ball-Foster	Milford, MA	0.2 lb/ton	NSPS	ESP	Soda Lime
Kimble Furnace "R"	Vineland, NJ	0.03***	NSR	ESP	Boro-silicate
Kimble Furnace "S"	Vineland, NJ	0.04 gr/dscf***	NSR	ESP	Boro-silicate

* Permit Limit ** Calculated *** Average of stack test results

Appendix D

NO_X Control Technologies
(Pollution Prevention)

Generally, NO_X emissions can be controlled in three ways: 1) by combustion modifications and 3) by post-combustion modifications to reduce NO_X after formation but before emission from the stack. Most of the control technologies that have been used to reduce NO_X emissions from gas furnaces have entailed a form of combustion modification. Most of the furnaces in New Jersey are currently meeting RACT requirements through the use of Electric Boost. This technology simply means that fuel is replaced with electric energy. Electric Boost is not a technology that is expected to be able to meet the SOTA performance levels recommended in this manual because of the cost of electricity. However, there are several furnaces that are using electric boost to meet these SOTA performance levels. In essence, electric boost uses electricity to replace a portion of the fuel used by the furnace. Its use to meet the lower emission levels recommended in this manual for SOTA is probably limited because of the high cost of additional electric boost that would be required. Add-on control devices such as selective catalytic reduction (SCR) and selective non-catalytic reduction (SNCR) which use ammonia (or urea in the case of some SNCR systems) to reduce NO_X emissions have not yet proven successful. SNCR has been used on two furnaces in California but has not achieved the control efficiency necessary to meet the SOTA performance levels. The two technologies that have been demonstrated to achieve the SOTA performance levels are the Oxy-Fuel system and the Pilkington 3R process. Table C-1 shows the control efficiency that these technologies have achieved and their applicability to different types of glass furnaces.

Table D-1
Control Efficiency and Applicability of NO_X Control Technology

Control Technology	% NO_X Reduction	Applicability
Oxy-fuel	85	Container glass, Fiberglass, and possibly Rolled Flat glass
Pilkington 3R	80	Flat glass, * Container glass

* = Expected but not demonstrated

These two technologies are described briefly below.

Oxy-Fuel System

The Oxy-fuel system is the substitution of oxygen for combustion air to burn the fuel in the glass furnace. Air is approximately 80 percent nitrogen and 20 percent oxygen compared to liquid oxygen which is 99.99 percent oxygen. The use of liquid oxygen significantly decreases the available nitrogen resulting in decreased NO_X formation. According to the US EPA Alternative Control Techniques Document (ACT), the oxy-fuel system could achieve about 85 percent reduction in NO_X emissions.

A technical report presented by Air Products and Chemicals, Inc. (APCI) at the 54th Glass Problems Conference in October 1993 indicated there are 9 fiberglass, 7 container glass, and 3 float glass furnaces in North America which have completed the conversion to partial oxy-fuel system using the Cleanfire burner. The Cleanfire burner was specifically designed for glass melting by APCI and Combustion Tec, Inc. which provides a low momentum, high luminous flame that gives broad coverage to the glass bath. In designing an oxy-fuel combustion system for a glass furnace, several factors need to be taken into consideration. These factors include: dimension of the furnace, pull rate, maximum firing rate, number and locations of the burners, flue location and size, batch charging, and refractory selection. Most of the furnaces which have been converted to oxy-fuel systems have been modeled using three dimensional Computational Fluid Dynamic modeling which enables visualization of temperature and velocity points in order to predict potential design issues. If there are potential problems predicted through modeling, the furnace layouts are modified prior to construction.

Pilkington 3R Process

The 3R process developed by Pilkington Glass Limited in United Kingdom is another control method for reducing NO_X emissions from glass furnaces which may achieve the SOTA performance levels in this manual. The 3R process uses various hydrocarbon fuels, injected into the furnace waste gas stream, as the agent to reduce NO_X to harmless nitrogen and water vapor. The 3R fuel does not burn but dissociates to form free radicals. The reactions are endothermic, i.e., they absorb energy. As a result there is no increase in regenerator temperatures or risk of burning down the checker work. Central to the 3R process is the technology to modify the operation of the furnace regenerators such that they become “reactors”, in addition to fulfilling their main roles in energy recovery and providing high levels of combustion air preheat essential for the productions of high quality glass. One of the key elements with the 3R process is that there is no change in the normal furnace temperature profile so there is no impact on furnace throughput or glass quality. The 3R process has been successfully tested on a wide range of glass melting furnaces, float, container, hollowware, gas-fire, and oil-fired, in outputs ranging from 7 to 700 tons/day. The 3R process has been installed, and is operating, on two flat glass furnaces in Europe. These installations and trials have shown that the process is suitable for most regenerative furnaces, and involves no fundamental change to the glass making process. It may be possible to apply the process on-the-run, requiring no disruption to furnace operation.

Appendix E

Particulate Matter Control Technologies

Historically, the control of emissions from glass furnaces has used wet scrubbing (venturi and packed beds), baghouses, and electrostatic precipitators (ESPs). These control technologies are described briefly below.

Wet Scrubbing

Wet scrubbing uses water particles to capture particulate matter in the gas stream. For particulate control, venturi scrubbers which atomize the water by forcing it through a venturi are commonly used. The efficiency of a wet scrubber is generally dependent upon the pressure drop. Scrubbers have not been widely used in the glass industry. However, a system consisting of a venturi and packed-bed scrubber with a pressure drop of 20-30 inches wc has been used to control emissions from container and opal glass operation. The high energy consumption and the complexity of treatment of liquid discharge required have appeared to limit its application.

Baghouse

Baghouses or fabric filtration relies upon a finely woven fabric to separate particles from the air stream as the air passes through the fabric. The design of a baghouse is generally dependent upon the air-to-cloth ratio. Both reverse-air cleaning and shaker-type baghouses with an air-to-cloth ratio of 2:1 to 4:1 have been used for particulate control. The high-temperature baghouse, using fiberglass bags operating in the range of 200 °C, functions only as a particulate remover. Because of the fine particulate, a rapid rise in pressure drop is encountered, resulting in short cleaning cycles. A rise in the "clean bag" pressure drop increases over time coupled with an operating pressure drop of 10-15 inches wc. The recovered product can be recycled back to the production process.

An air-to-cloth ratio of 2:1 to 4:1 has been unachievable with the fuel-air mixtures in glass furnaces during the last 30 years. The high volumetric flow of air increases the A/C ratio to an undesirable design value.

Electrostatic Precipitator

Electrostatic precipitators use electricity to charge particles in a gas stream. The electrically charged particles are attracted to an oppositely charged plate where they are collected. The ESP has been the predominant air pollution control system used in the glass industry. It functions only as a particulate separator and has provided reliable performance for container glass operators. The particulate emissions are low, in the range of 20 mg/nm^3.

Adhesion problems of the collected particulate to the electrodes have occurred in borosilicate glass applications. The material recovered by the ESP can be recycled to the glass-making process.